CLARREO Pathfinder Inter-calibration: Requirements, Objectives & Opportunities

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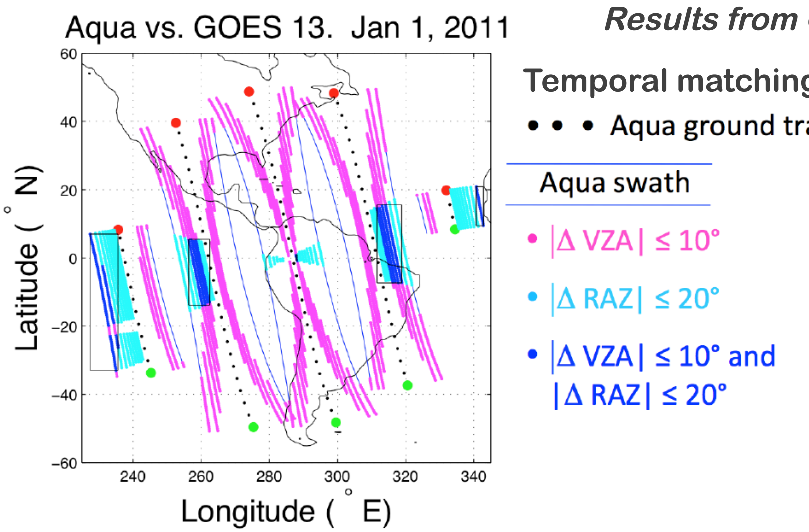
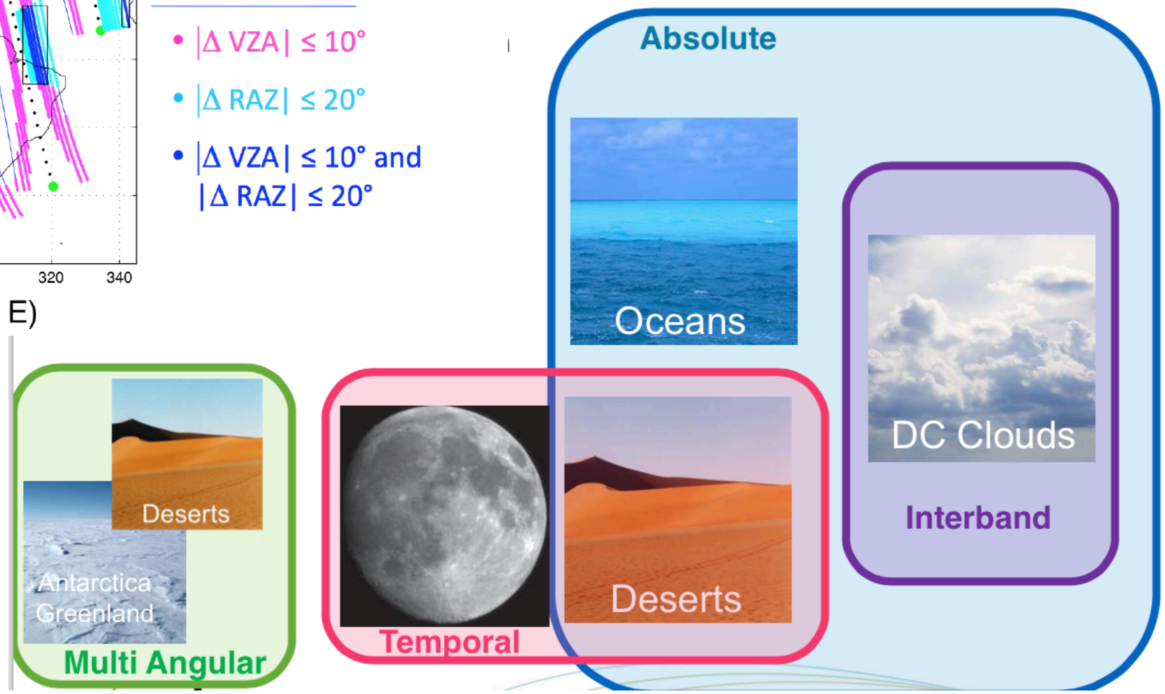
Outline:

- ✧ Inter-calibration of sensors: background
- ✧ Mission Requirements & Success Criteria
- ✧ On-orbit pointing approach for inter-calibration
- ✧ Instrument Field-of-Regard from ISS location
- ✧ Other Inter-calibration opportunities
- ✧ Inter-calibration event prediction & sampling
- ✧ Inter-calibration data products
- ✧ Publications

Inter-Calibration of Sensors in RS: Current

Results from C. Roithmayr



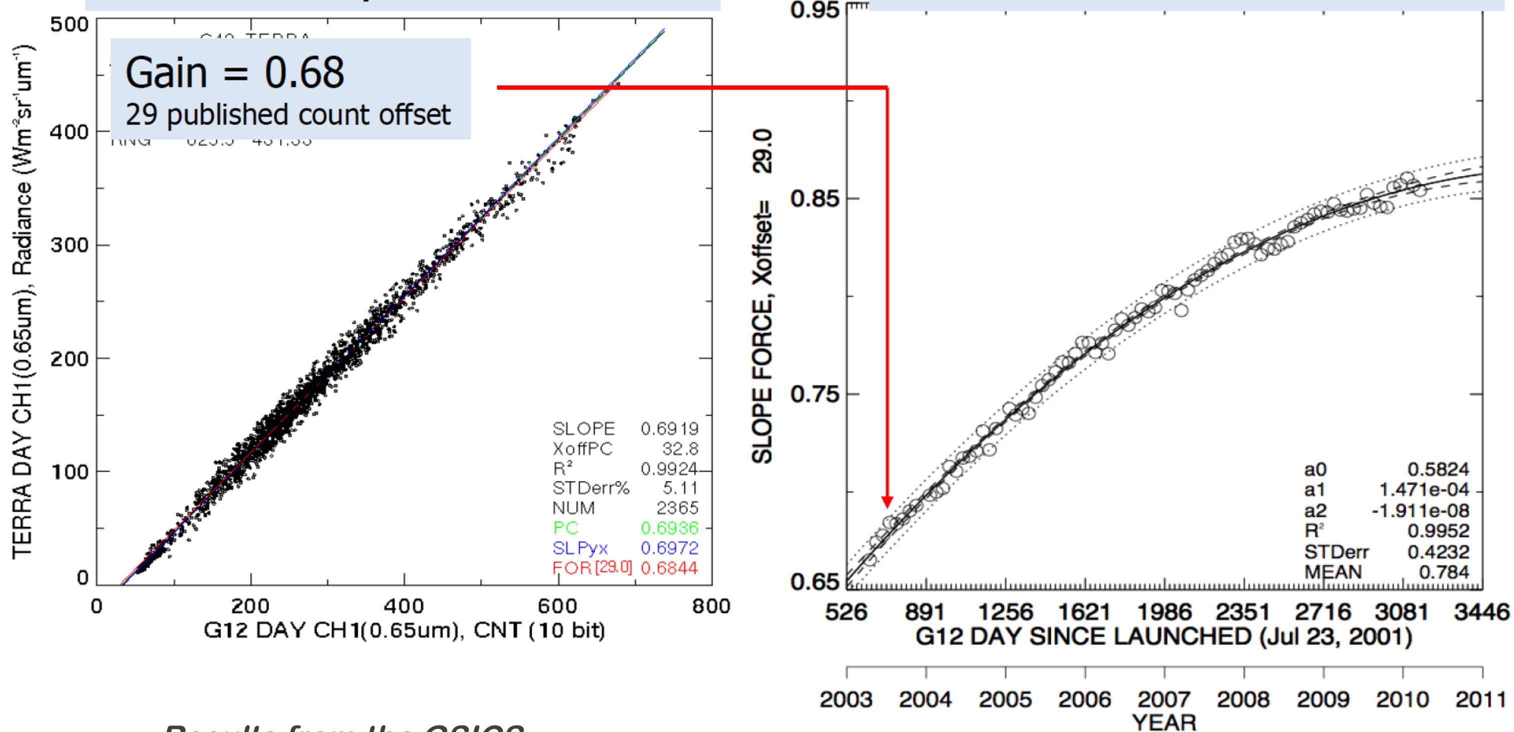


- ✧ LEO and GEO data matching when available (e.g. MODIS and GOES-13).
- ✧ Uniform and stable surface sites.
- ✧ Instrument stability by observing the Moon (e.g. SeaWIFS).
- ✧ Deep Convective Clouds, clear ocean & deserts: involve RT modeling.

Inter-Calibration of Sensors in RS: Current

GOES-12/Terra-MODIS July 2003

GOES-12 gain based on Terra-MODIS



Results from the GSICS

Fundamental limitation of current approach

Inter-calibration of gain:

- Type A uncertainty (random) is 5.11% (k=1): due to data matching.
- Type B uncertainty (not random) is defined by the MODIS accuracy of 2% (k=1) [pre-launch].
- Spectral Type B uncertainty: due to difference in spectral response.

Inter-Calibration Objectives & Requirements

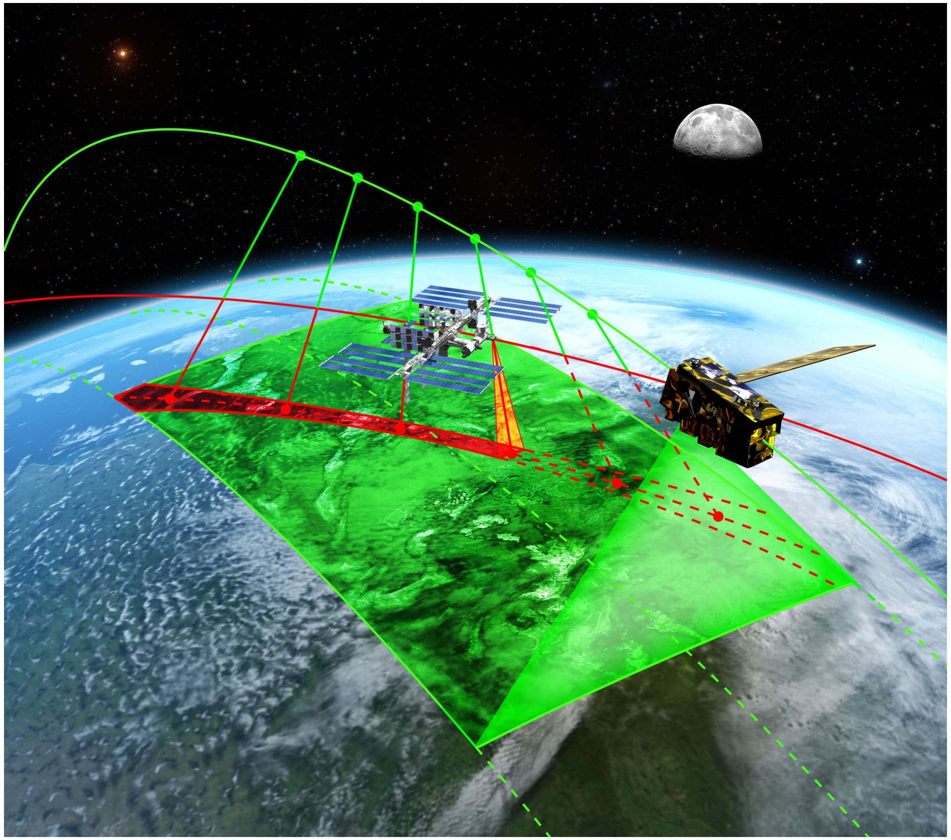
Baseline Science Objectives:

The CLARREO Pathfinder objective is to demonstrate the ability to use the reflected solar spectrometer as an in-orbit transfer standard for inter-calibration of the reflectance bands of the VIIRS instrument and the CERES instrument's shortwave channel. The uncertainty contribution from inter-calibration approach should be limited to 0.3% (k=1).

Threshold Science Requirements:

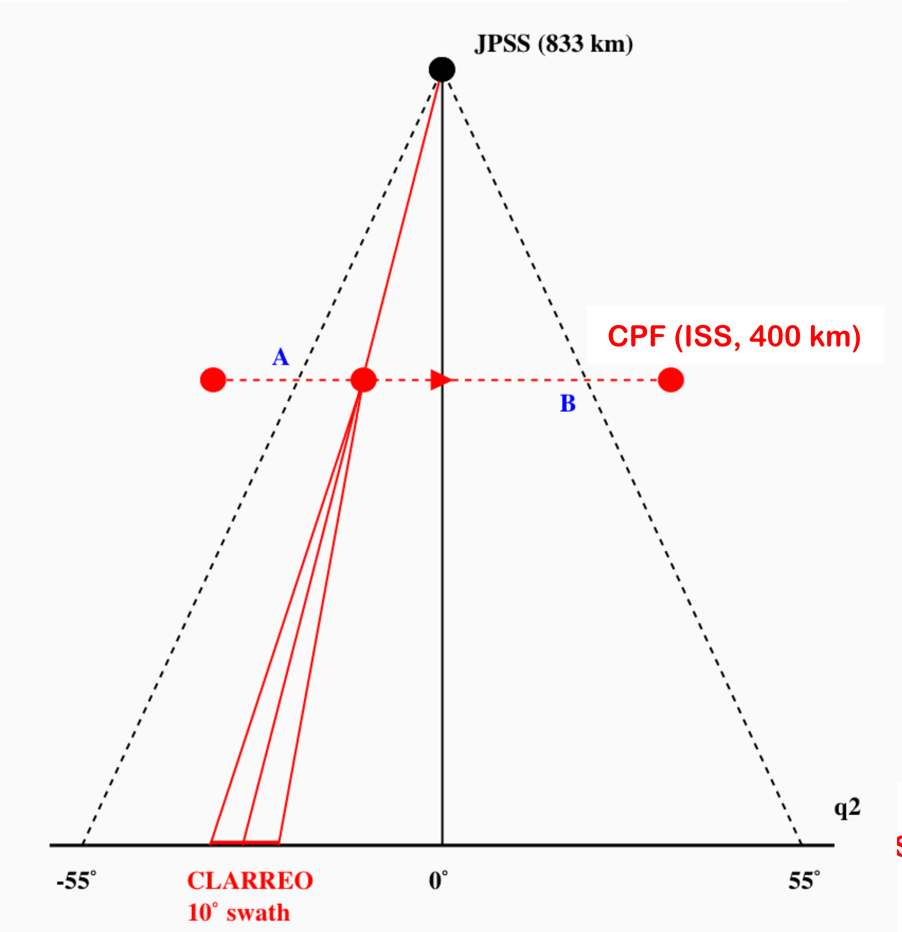
The CLARREO Pathfinder shall demonstrate the ability to use the reflected solar spectrometer as an in-orbit transfer standard for inter-calibration of the reflectance bands of the VIIRS instrument and the CERES instrument's shortwave channel. The uncertainty contribution from inter-calibration approach should be limited to 0.6% (k=1).

Inter-Calibration Concept: CERES & VIIRS

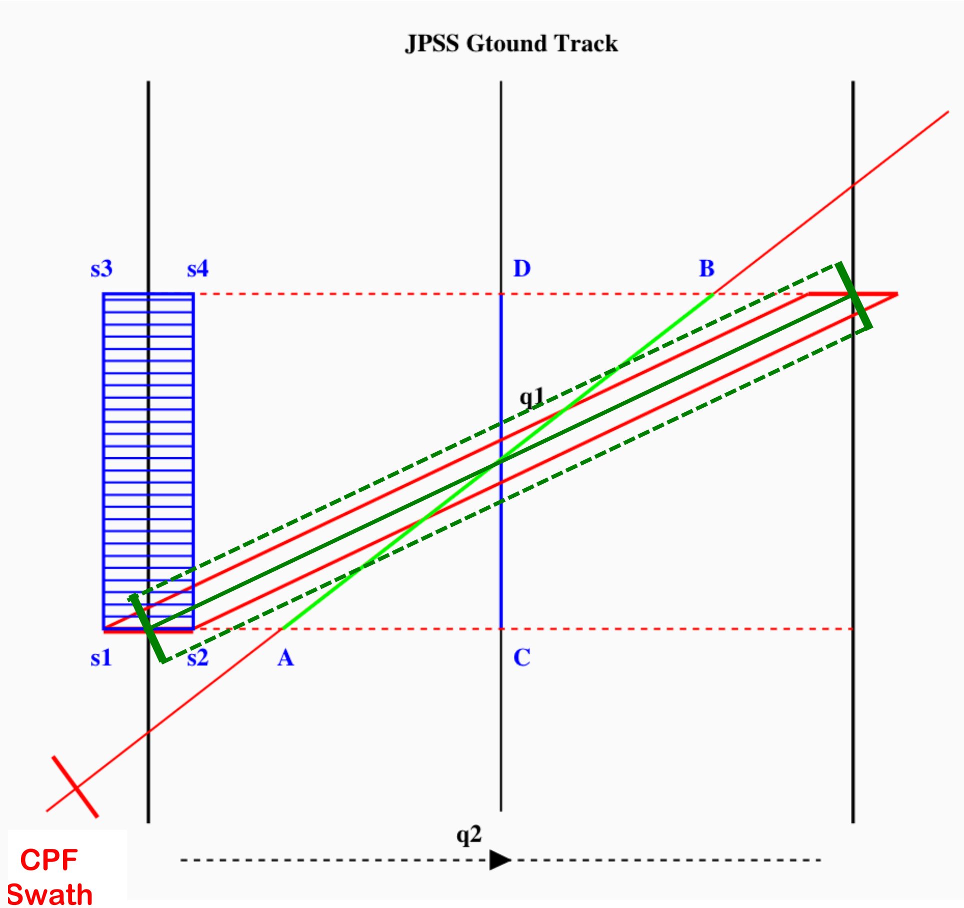


- CLARREO Pathfinder Instrument provides high-accuracy reference on orbit.
- CLARREO Pathfinder Instrument has 2D pointing ability for real-time data matching.
- CLARREO Pathfinder data matching with CERES and VIIRS on JPSS: temporal matching within 10 minutes, on-orbit angular/spacial matching.
- CLARREO Pathfinder location on ISS: ELC-1 Site 3.

Inter-Calibration of Sensors: CERES & VIIRS



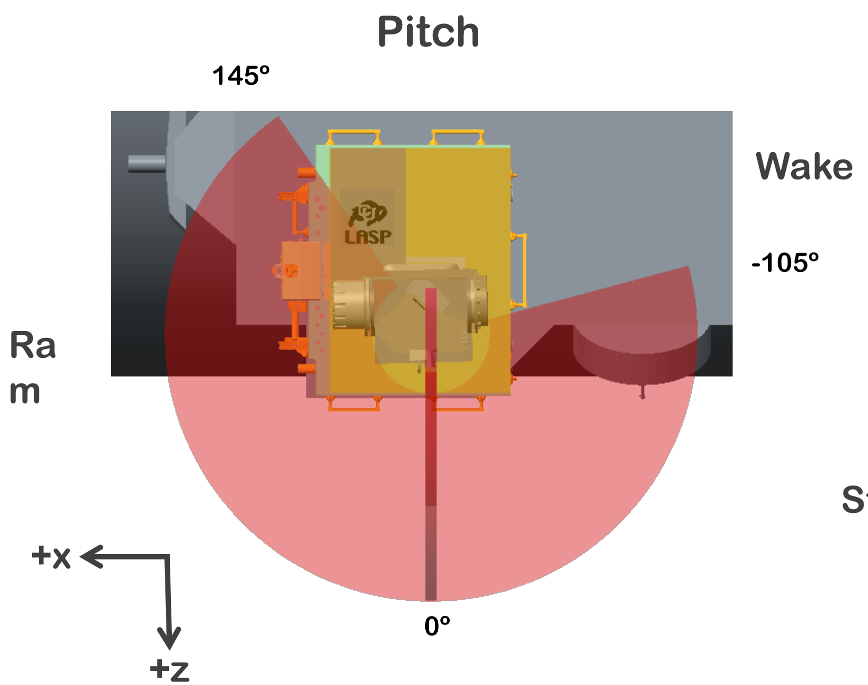
Projection in JPSS cross-track plane

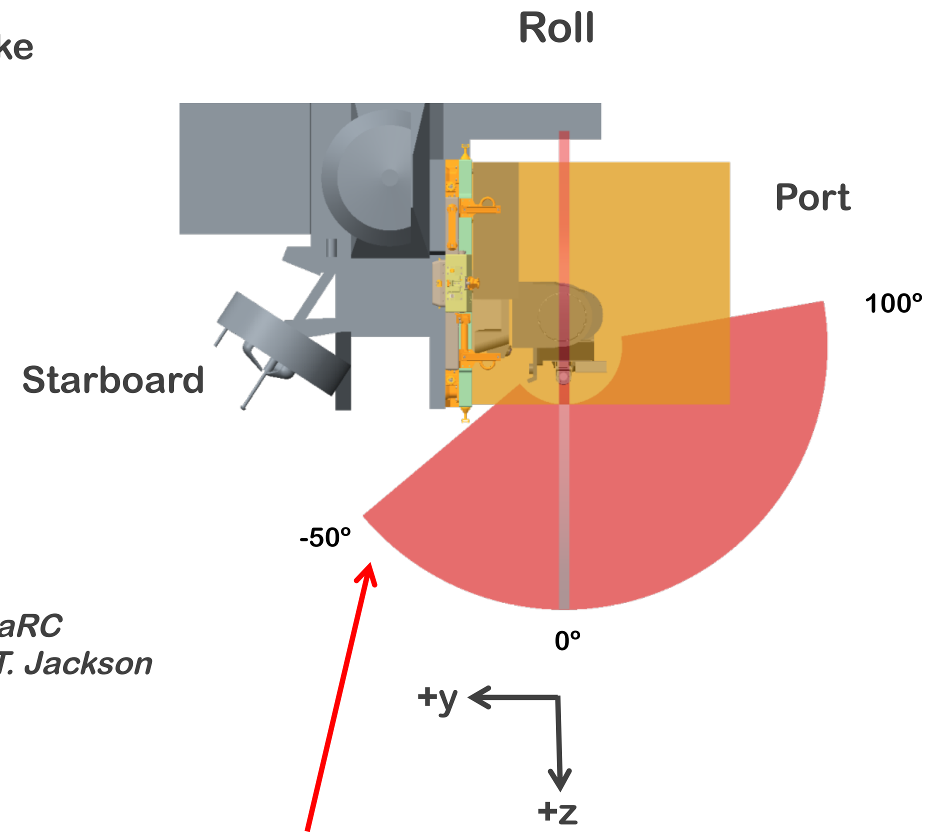


Top view

Red: full CLARREO approach
Green: CLARREO Pathfinder approach

RS Instrument Field-of-Regard





Accommodation studies by the NASA LaRC Engineering team: J. Leckey, C. Boyer, T. Jackson

- Gimbal configuration: pitch - roll
- Approximate gimbal range of motion at ISS ELC-1 Site 3.
- Not all pointing angles are available due to ISS accommodation.
- Refine analysis for ISS components affecting RS instrument view in Phase-A.

Inter-Calibration Event Prediction

- **New approach: first inter-calibration by real-time pointing off-nadir !**
- **Inter-calibration on-orbit operations are planned ahead of time !**

(1) Inter-calibration of Sensors:

- Prediction by orbital modeling
- Filter out events with instrument FOV obscured by ISS fixed and rotating structures
- Assess the value for every event by modeling
- Deliver event parameters to instrument operations team

(2) Calibration of Lunar Spectral Reflectance:

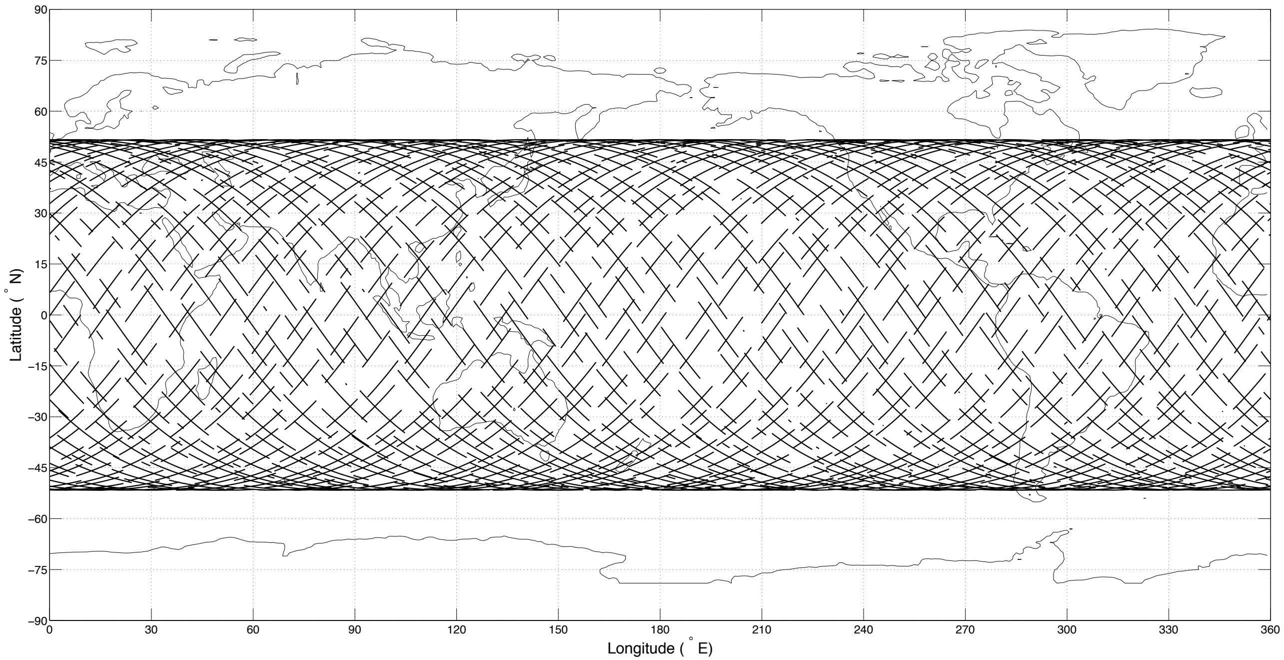
- Prediction of Moon viewing by orbital modeling
- Filter out events with instrument FOV obscured by ISS fixed and rotating structures
- Assess the value for every lunar geometry by modeling
- Coordinate with the instrument calibration team
- Deliver event parameters to instrument operations team

(3) Characterization of Surface Sites:

- Prediction by orbital modeling
- Filter out events with instrument FOV obscured by ISS fixed and rotating structures
- Assess the value for every event by modeling
- Deliver event parameters to instrument operations team

Inter-Calibration Events: Geolocation

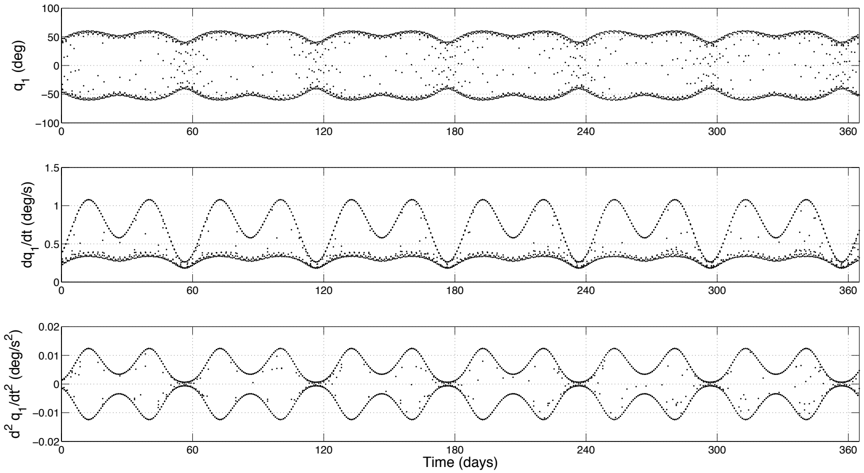
Results from C. Roithmayr



Geolocation of the ISS ground track during each opportunity to take measurements for inter-calibrating JPSS cross-track sensors (CERES and VIIRS).

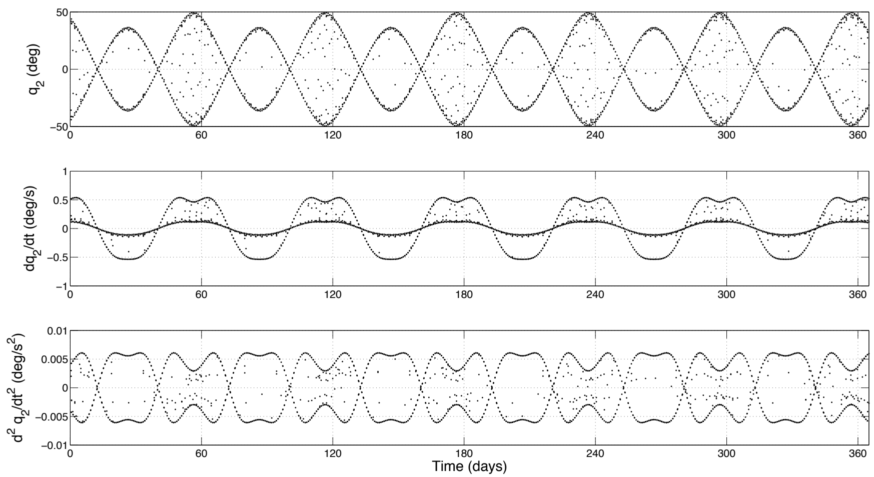
- Instrument FOV = 10º
- Time matching +/- 10 minutes
- 1262 inter-calibration opportunities over 1 year

Inter-Calibration Events: Gimbal Motion



Results from C. Roithmayr

Behavior of the gimbal: for each opportunity, the maximum and minimum gimbal angle q1, angular speed d(q1)/dt, and angular acceleration $d^2(q1)/dt^2$ are shown in the top, middle, and bottom plots, respectively.

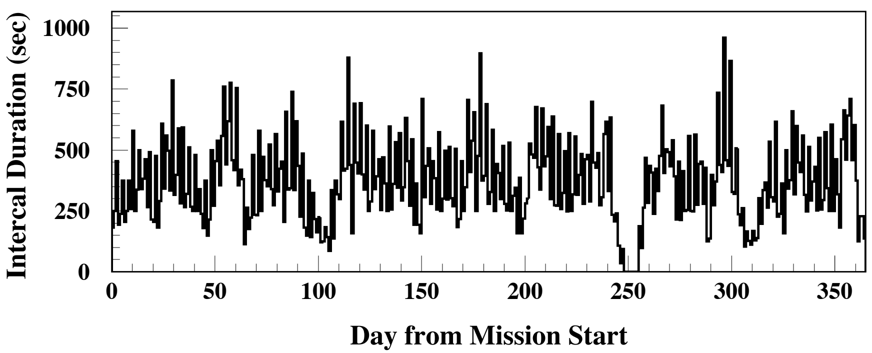


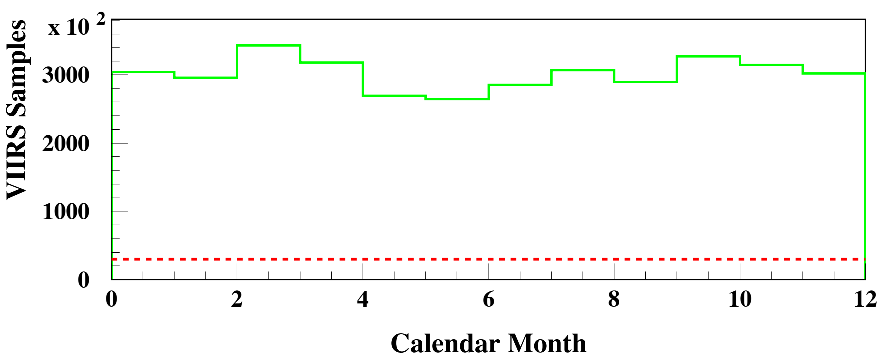
Behavior of the gimbal: for each opportunity, the maximum and minimum gimbal angle q2, angular speed d(q2)/dt, and angular acceleration $d^2(q2)/dt^2$ are shown in the top, middle, and bottom plots, respectively.

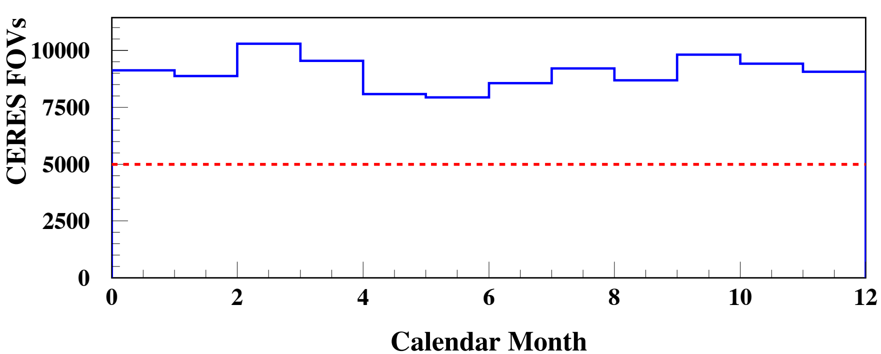
q1 – pitch angle
q2 – roll angle

Inter-calibration with CERES and VIIRS on JPSS

Inter-Calibration: Sampling & Margin







Simulation ISS ELC-1 Site 3:

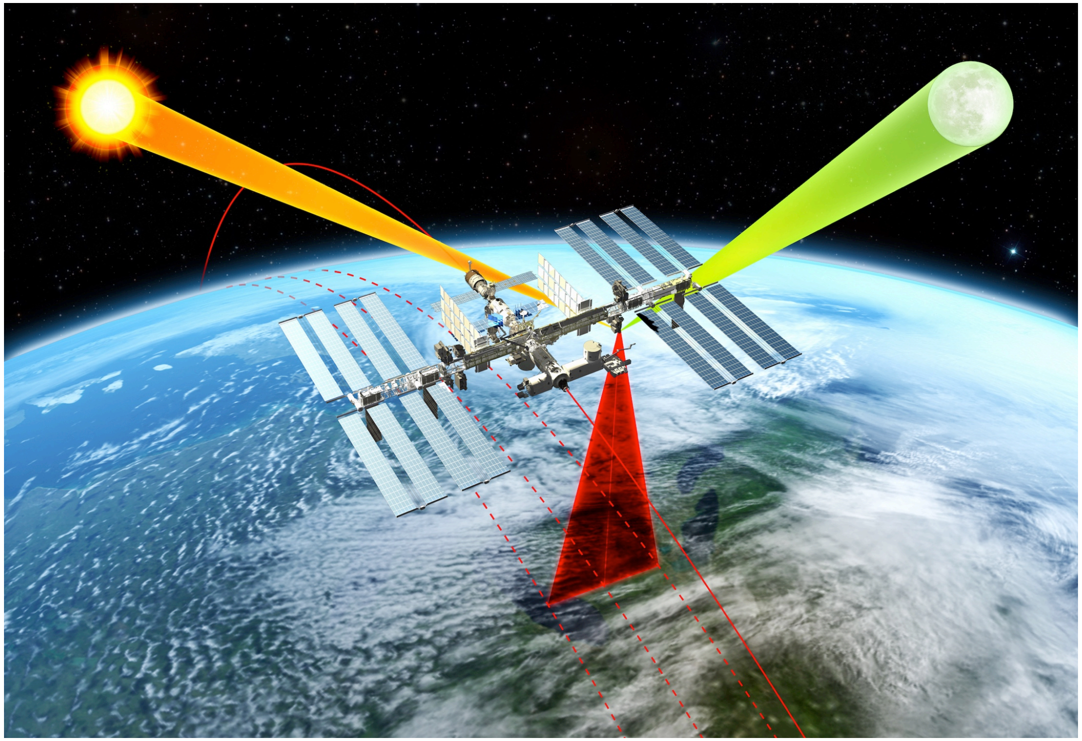
- ✧ 10 minutes time matching
- ✧ Instrument field-of-regard
- ✧ Instrument FOV = 10º
- ✧ Instrument FOV obscuration = 0%
- ✧ Event duration > 30 seconds
- ✧ SZA < 75º
- ✧ N good events = 1163

VIIRS:
100 samples every 5 seconds
(imager re-sampling)

CERES:
3 FOVs every 5 seconds
(large FOV)

Margin at 44% for operations not-available on average !

Other Inter-Calibration Opportunities



SENSORS:

- GEO imagers:
  NOAA ABI on GOES-16
  EUMETSAT
  ESA GERB
- Land imagers:
  USGS Landsat
  ESA Sentinel-2A/B

CALIBRATION TARGETS:

- Instrumented and not-instrumented Surface Sites (deserts)
- Moon: improve accuracy of lunar spectral reflectance

Inter-Calibration Data Products

Product	Contents	Resolution	Granule
Level-1 Products for VIIRS CERES GEO (NOAA, ESA, etc.) Landsat (USGS) Surface Sites Moon	Calibrated and geo-located CPF observations.	Full spectral and spatial resolution of the CPF RS Instrument.	Each granule contains single CPF inter-calibration event.
Level-4 Products for VIIRS CERES	Collections of CPF (Level-1), VIIRS, and CERES matched data (Level-1 & Level-2).	CLARREO (Level-11) and VIIRS (Level-1 & Level-2, Clouds and Aerosols) data spatially convolved over IC sample. CLARREO Spectral re-sampling. CLARREO (Level-1) spatially convolved over CERES FOV's PSF. CLARREO conversion to broadband reflectance. Scene ID from the CERES SSF.	Data processed by the CPF inter-calibration events.
Level-4 Products for VIIRS CERES	Inter-calibration results: Constraints on effective offset, gain, non-linearity, sensitivity to polarization, and spectral degradation.	N/A	N/A

❖ Additional data analysis – by a separately funded science team

CLARREO Inter-Calibration: Key Publications

Roithmayr, C.M., and P.W. Speth, 2012: “Analysis of opportunities for intercalibration between two spacecraft,” Advances in Engineering Research Vol. 1, Chapter 13, Edited: V.M. Petrova, *Nova Science Publishers*, Hauppauge, NY, pp. 409 - 436.

Lukashin, C., B. A. Wielicki, D. F. Young, K. Thome, Z. Jin, and W. Sun, 2013: “Uncertainty estimates for imager reference inter-calibration with CLARREO reflected solar spectrometer,” *IEEE Trans. on Geo. and Rem. Sensing, special issue on Intercalibration of satellite instruments*, 51, n. 3, pp. 1425 – 1436.

Roithmayr, C. M., C. Lukashin, P. W. Speth, G. Kopp, K. Thome, B. A. Wielicki, and D.F. Young, 2014a: “CLARREO Approach for Reference Inter-Calibration of Reflected Solar Sensors: On-Orbit Data Matching and Sampling," *IEEE TGRS*, v. 52, 10, pp. 6762 - 6774.

Roithmayr, C. M., C. Lukashin, P. W. Speth, D.F. Young, B.A. Wielicki, K. J. Thome, and G. Kopp, 2014b, “Opportunities to Intercalibrate Radiometric Sensors from International Space Station,” *J. of Atm. and Oce. Tech.,* DOI: 10.1175/JTECH-D-13-00163.1.

Wu, A., X. Xiong, Z. Jin, C. Lukashin, B.N. Wenny, J.J. Butler, 2015: “Sensitivity of Intercalibration Uncertainty of the CLARREO Reflected Solar Spectrometer Features,” IEEE TGRS, v. 53, 4741 - 4751, 10.1109/TGRS.2015.2409030

Sun W., C. Lukashin, and D. Goldin, 2015: “Modeling polarized solar radiation for CLARREO inter-calibration applications: Validation with PARASOL data," *J. Quant. Spectrosc. Radiat.*, v. 150, pp. 121 - 133.

Sun, W., R.R. Baize, C. Lukashin, and Y. Hu, 2015: “Deriving polarization properties of desert-reflected solar spectra with PARASOL data,” *Atmos. Chem. Phys.*, 15, 7725 - 7734, doi: 10.5194/acp-15-7725-2015.